



# Turbulence Detection & Mitigation Element

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*Hampton, Virginia - May 23-25 2000*



# Briefing Outline

Scope/Background

Accident Assessment Conclusions

Requirements

Goal

Approach

Relationships to Outside Groups

Technical Approach

WBS structure, Roadmaps, Deliverables, Tech Transfer

FY98-00 Results/Accomplishments to Date and Plans

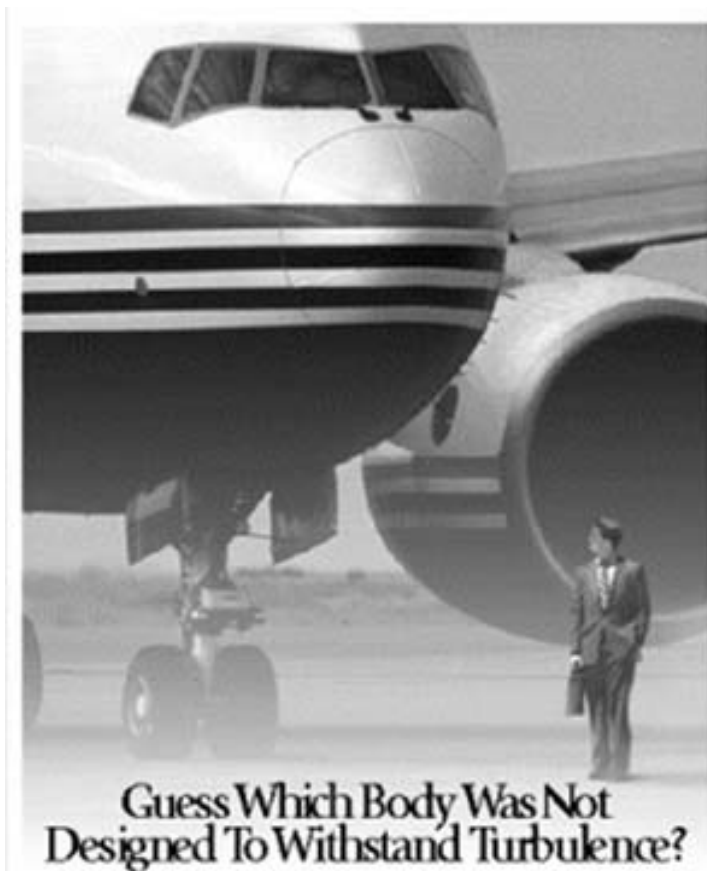
Resources and Facilities

Risk Assessment and Mitigation

Summary

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# Scope of Turbulence Effort



- Turbulence from Natural Atmospheric Processes (+ Enroute Wake Vortex)
- Parts 121, 135, and 91 (Scheduled Carriers, Commuters & GA)
- Both Strategic (before TO) & Tactical (Enroute)
- Both Avoidance & Encounter Mitigation

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# Background

- Turbulence Costs
  - Leading Cause of In-Flight Injuries
  - Cost estimated at >\$100M/yr. for airlines
- Turbulence Initiators
  - Convective Storms (within and as far as 40 miles away from visible clouds in clear air)
  - Jet Stream (at confluence of multiple streams and near boundaries)
  - Mountain Wave (upward propagating from disturbances near the surface)



# Conclusions from Accident Assessment

- GA and Air Carriers have fundamentally different Turbulence Accident Statistics
  - GA problems mostly below 15 kft, Air Carriers mostly above (not too surprising)
  - GA problems mostly with Convective Turbulence, Air Carriers about 50/50 Convective/Clear-Air
- Warning may have an impact on accident statistics
  - 84% of encounters had no crew warning
- Seat-Belt Sign status had little effect on injuries - BUT a believable warning may impact injuries
  - In 64% of the encounters, the seat belt sign was ON
- Keeping Passengers belted has little or no effect on Attendant Injuries (not too surprising)
  - In 73% of the encounters Flight Attendants were injured

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# Requirements in Response to Accident Data Conclusions

- **Reliable Tactical Warning**
  - Provide timely warning to deviate or to institute cabin safety measures
  - Provide real-time alerts to AWIN network
- **Reliable Forecasting/Nowcasting**
  - Collaborate with FAA to provide improved Forecasting/Nowcasting at useful resolutions for pre-takeoff strategic turbulence avoidance planning
- **Encounter Mitigation**
  - Develop technology to reduce severity of turbulence encounter experience



## Goal

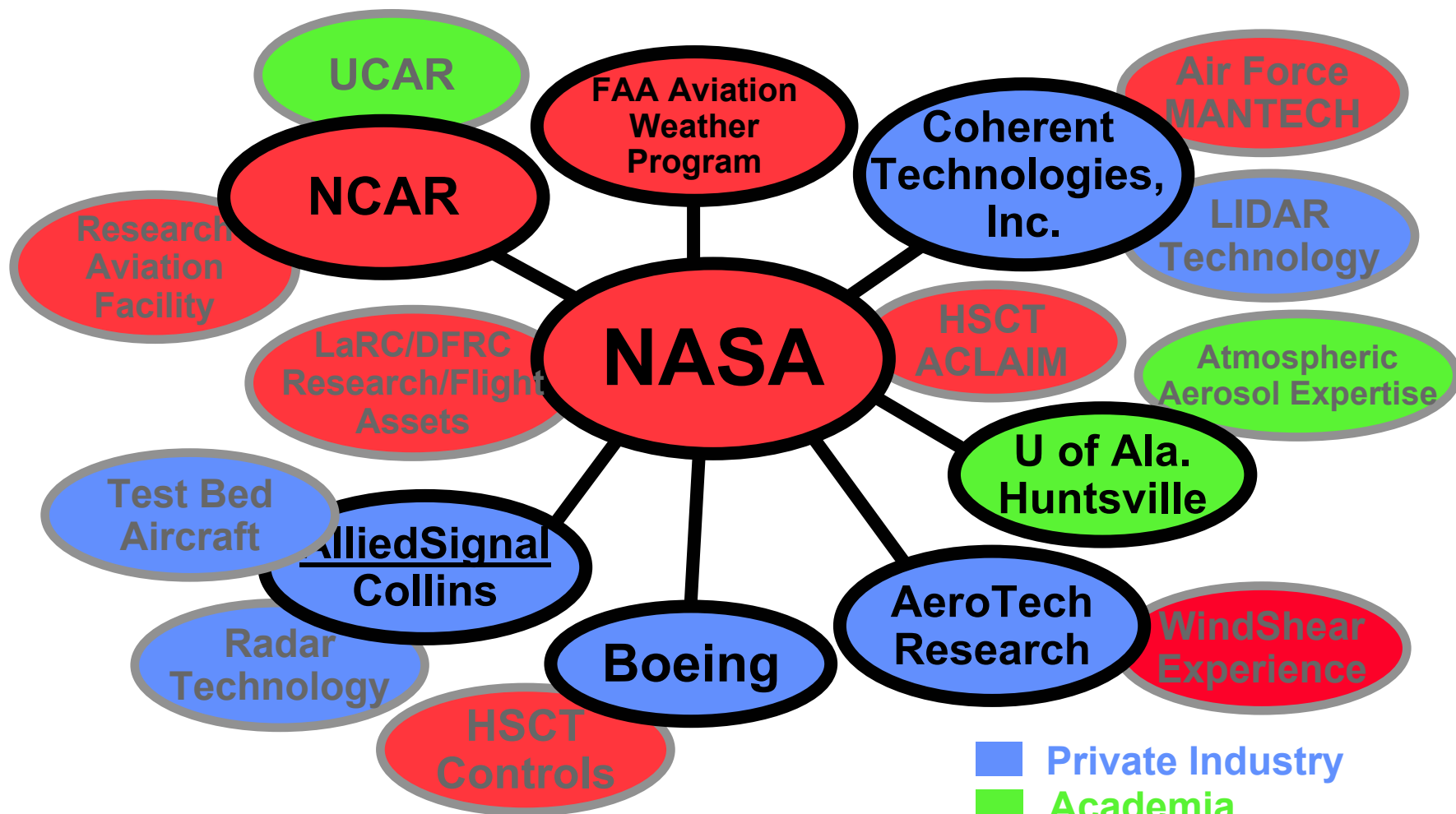
- To reduce the risk of turbulence-induced injury or death to the traveling public and airline staff by 80% in 10 years.



# Approach

- Build a Turbulence Team from Industry, Academia, and Government to address requirements, approaches, and solutions
- Utilize the Commercial Aircraft Safety Team (CAST) to determine requirements for Air Carriers (<http://www.cygnacom.com/turbulence/>)
- Address Air Carrier Issues with Technology Approaches Combined with Rule-Making, and Improved Procedures
- Address GA Issues with improved Weather Products Disseminated through AWIN

# Turbulence Team Relationships



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## WBS Structure

### Detection

- Sensor Performance Assessment
- Sensor Development
- Requirements Definition (CAST)

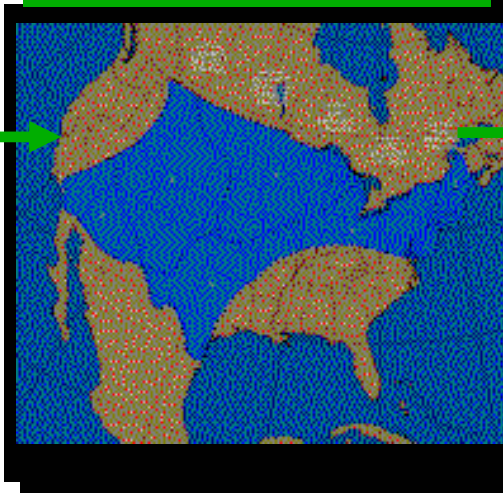
- Algorithm Development
- Demonstration & Verification

Turbulent Tolerant Flt. Control Algorithm

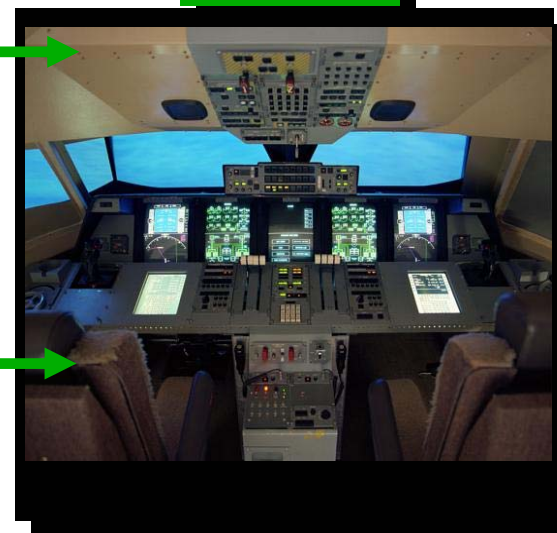
### Turbulence Characterization



### Forecasting/Nowcasting



### Mitigation

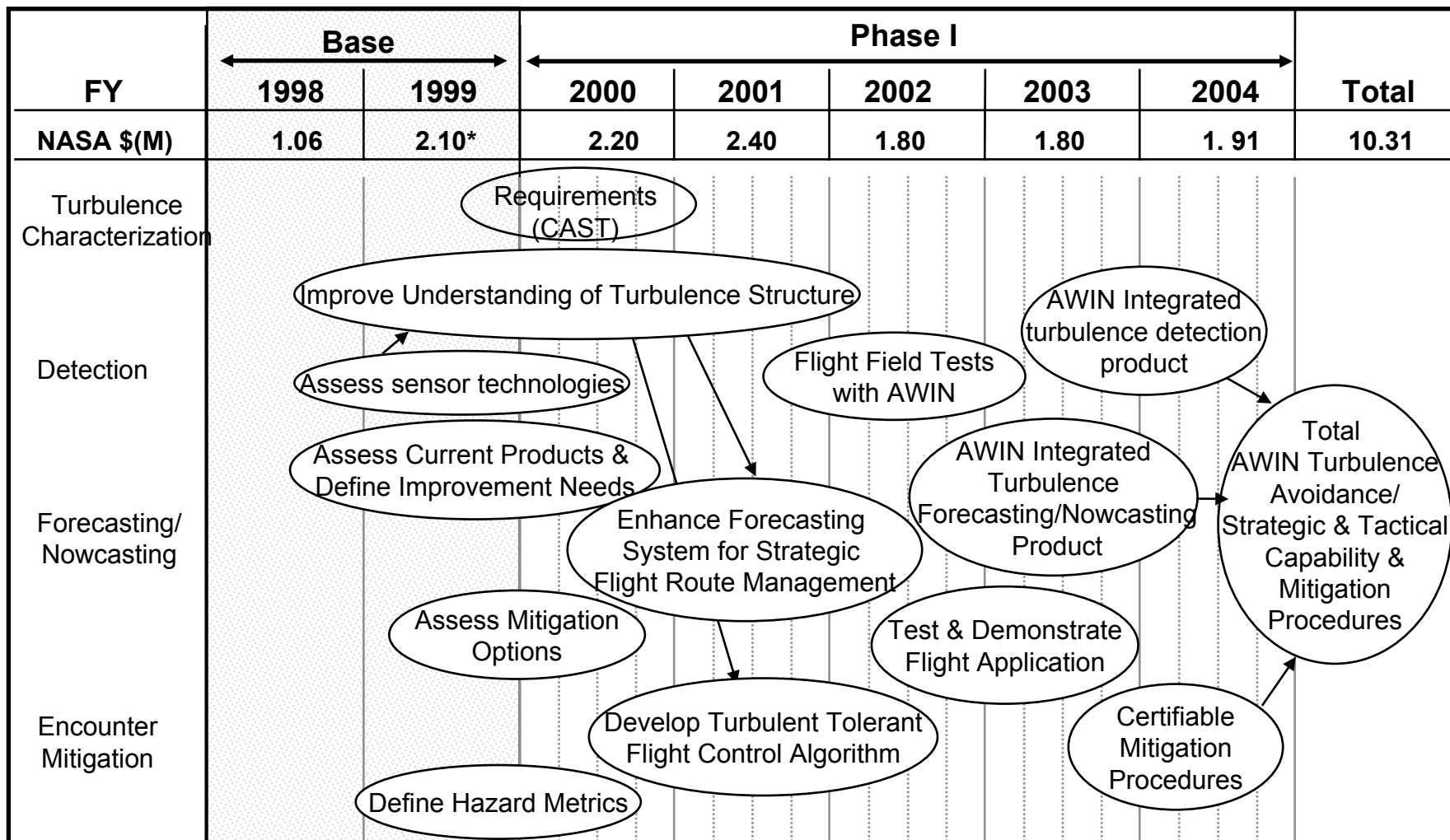


- Severe Events Database
  - Hazard Metric Development
  - Assessment of Existing Turbulence
- Products

- Demonstration & Verification
- Strategic Route Management

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# Technical Approach - Roadmap



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# Technical Approach - Major Deliverables/Products

- Detector Technology
  - Radar (software)
  - Lidar (hardware/software)
- Forecast Technology and Applications Support
  - Atmospheric gust characterization (300-3kft scale)
  - Small-scale atmospheric dynamics diagnostics
  - Route deviation cost trades/traffic management impacts
- Encounter Mitigation Technology
  - Flight management systems for turbulence penetration
  - Airframe systems for improving ride quality

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# Technical Approach - Technology Transfer

- Upgrade Existing Installed Base
  - Weather radar turbulence algorithm
  - Turbulence tolerant flight control system
- Industry Buy-In
  - CAST requirements definition
  - Industry-based JSAT & JSIT groups
- Multi-Functional Technology
  - Lidar winds aloft

# Team Accomplishments

- **Teamed with Industry, Academia, & Government to assure comprehensive Requirements, Approaches, and Solutions**
  - Collaborating using in-kind resource sharing minimizes funds transfer and procurement lead-time
  - Variety of perspectives reduces risk
- **Flight tested ACLAIM forward-looking turbulence sensor**
  - Detected light to moderate turbulence at ranges between 3 and 6 miles ahead
  - Penetrated turbulence to verify
  - Operated 15 hours in a variety of conditions from ground to 25k ft.
  - No turbulence encountered that was not predicted



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## Team Accomplishments (cont.)

- **Supporting FAA AWR in-situ turbulence measurement program (jointly funded)**

- Eventual deployment in ~350 commercial aircraft to acquire turbulence accelerations
- Early results expected within 2 years
- Supports turbulence characterization work/auto PIREP



- **Collaborating with industry partners to develop airborne Turbulence Sensing Systems using RADAR and LIDAR technology**

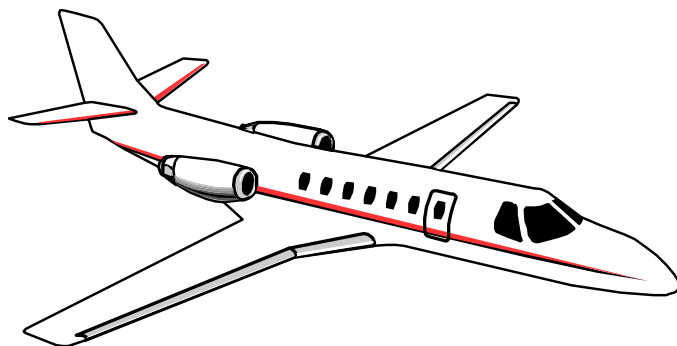
- Expected initial target fleet deployment within 3 years
- B-757 flight tests scheduled for FY00 and FY01



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# Team Accomplishments (cont.)

- **Collaborated with FAA to Organized Turbulence Workshop**
  - Strong cooperative interaction and mutual support
  - Continuing support from Stakeholder Groups
  - Genesis for initiating Commercial Aviation Safety Team (CAST) Assessment



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# Team Accomplishments (cont.)

- **Explored low moisture turbulence environment in Greeley deployment**
  - Compared ground and airborne radar measurements of convectively-induced turbulence in low dBz conditions
  - Penetrated turbulence to verify
  - 13 missions flown into turbulence over 3 week period
  - Teamed with NCAR, Honeywell, Rockwell, So. Dak. Sch. of Mines, Univ. of Colorado, NASA



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# Team Accomplishments (cont.)

## • Commercial Aircraft Safety Team (CAST)

- Joint Safety Analysis Team (JSAT) began operation in October 1999
- FAA, ALPA & NASA Co-Chairs
- 35 Members from Aviation Community
- 6 Meetings Convened
- ~ 30 Interventions Identified
- Expected completion by 30 September 2000



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# Resources and Facilities

- **Testbed Aircraft**
  - B757, DC-8, C-17, LearJet (govt.)
  - L-188 Electra (NCAR)
  - Convair 580, T39 (private industry)
  - T-28 (Univ. North Dakota)
- **Simulators**
  - Aircraft
  - IESS (Radar)
- **Aircraft Models**
  - B-747
  - B-757
  - B-737



# Risk Assessment & Mitigation

- **Cost prevents affordability**
  - Multi-function capability
  - Emphasis on reducing manufacturing costs
- **Anticipated infrastructure not ready**
  - Scale back work to individual aircraft protection
- **Detection technology performance falls short**
  - Alert ranges reduced
  - Less sensitivity to low turbulence levels



# Summary - Status of Elements

- **Turbulence Characterization**
  - Hazard metric work started
  - Receiving added emphasis with funding augmentation
- **Detection**
  - Radar flight tests in FY-00
  - Lidar flight tests in FY-00?
- **Forecasting/Nowcasting**
  - Initial FY00 start-up planning activity
  - Turbulence forecast support planning for B-757 FY-00/01 field research flights
  - Injury case study simulations with MASS and TASS models
- **Encounter Mitigation**
  - Assessing performance of existing control systems in turbulence

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# Peanuts Perspective



Turbulence is NO Laughing Matter

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